

PATENT

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# UTILITY PATENT APPLICATION TRANSMITTAL LETTER AND FEE TRANSMITTAL FORM (37 CFR 1.53(b))

BOX PATENT APPLICATION

Commissioner for Patents

Washington, DC 20231

Sir:

Transmitted herewith for filing under 37 CFR 1.53(b) is:

- ☒ a patent application  
☐ a Continuation ☐ a Divisional ☐ a Continuation-in-Part (CIP)  
 of prior application no.: \_\_\_\_\_; filed  
☐ A Small Entity Statement(s) was filed in the prior application; Status still proper and desired.

Inventor(s) or Application Identifier:

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Entitled: **SECURE DATA STORAGE AND RETRIEVAL IN A CLIENT-SERVEER  
ENVIRONMENT**

Enclosed are:

1. ☒ Application Transmittal Letter and Fee Transmittal Form (*A duplicate is enclosed for fee processing*)
2. ☒ 71 pages of Specification (including 84 claims)
3. ☒ 12 sheets of Formal Drawings (35 USC 113)
4. ☒ Oath or Declaration
  - a. ☒ newly executed (*original or copy*)
  - b. ☐ copy from prior application (37 CFR 1.63(d) (*for continuation/divisional*)) [Note Box 5 Below]
  - c. ☐ **DELETION OF INVENTOR(S)** (*Signed statement deleting inventor(s) named in the prior application*)
5. ☐ Incorporation By Reference (*useable if box 4b is checked*)  
 The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. ☐ Microfiche Computer Program (*Appendix*)
7. ☒ Assignment papers (*cover sheet(s) and document(s)*)
8. ☐ Small Entity Statement(s)
9. ☐ Information Disclosure Statement, PTO-1449, and \_\_\_\_\_ references cited
10. ☐ Preliminary Amendment (*Please enter all claim amendments prior to calculating the filing fee.*)
11. ☐ English Translation Document
12. ☐ Certified Copy of \_\_\_\_\_ Application No. \_\_\_\_\_; Filed \_\_\_\_\_

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 08/21/00

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13. ☐ Sequence Listing/ Sequence Listing Diskette  
a. ☐ computer readable copy  
b. ☐ paper copy  
c. ☐ statement in support  
14. ☐ An Associate Power of Attorney  
15. ☒ Return Receipt Postcard (MPEP 503) (Should be specifically itemized)  
16. ☐ Other:

The fee has been calculated as shown below:

	Column 1 No. Filed	Column 2 No. Extra	Small Entity Rate Fee	Large Entity Rate Fee
BASIC FEE			\$345.00	\$690.00
TOTAL CLAIMS	84- 20 =	64	x 9 = \$	x 18 = \$1152.00
INDEP CLAIMS	3 - 3 =	0	x 39 = \$	x 78 = \$
<input type="checkbox"/> MULTIPLE Dependent Claims Presented			+ 130 = \$	+ 260 = \$
If the difference in Col. 1 is less than zero, Enter "0" in Col. 2			Total \$	Total \$1842.00

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☐ A check in the amount of \$ is enclosed to cover the filing fee, PLUS the Assignment Recordation fee (\$40.00).  
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☐ The Commissioner is hereby authorized to credit overpayments or charge the following fees associated with this communication to Deposit Account No. 09-0461.  
a. ☐ Additional filing fees under 37 CFR 1.16 for presentation of extra claims.  
b. ☐ Additional patent application processing fees under 37 CFR 1.17.

Respectfully submitted,

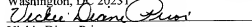
  
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Date of Signature: August 21, 2000

## SECURE DATA STORAGE AND RETRIEVAL IN A CLIENT-SERVER ENVIRONMENT

### Related Applications

5 The present application is related to United States Patent Application Serial No. \_\_\_\_\_, entitled "SECURE DATA STORAGE AND RETRIEVAL WITH KEY MANAGEMENT AND USER AUTHENTICATION", Attorney Docket No. 5577-208, the disclosure of which is incorporated by reference as if set forth fully herein.

### Field of the Invention

10 The present invention relates to data processing systems and more particularly to the security of stored digital data.

### Background of the Invention

15 With an ever increasing awareness among the public as to the privacy of digitally stored data, much attention has been focused on mechanisms for providing secure files and/or file access. Such security may become ever more important as, for example, more and  
20 more information is stored in a "file server" format. For example, with the recent introduction of publicly

accessible "Internet hard disks" where files of many different, and often unrelated, users are stored on Internet accessible servers, the issue of file security may become even more important. As is evidenced by, for example, the systems identified below, many differing solutions have been proposed to the problem of file security.

One conventional file security system is described in Allen G. Konheim, *Cryptography, A Primer*, John Wiley & Sons, New York, 1981, pp. 348-363, describes a file security system called the Information Protection System (IPS). In IPS, each user has a secret passphrase, which is hashed by the system to produce a file encryption key. The file encryption key is then used to encrypt/decrypt that user's files. The encrypted files for all users are stored in a common system database. Each enciphered file has a file header. The file header contains such information as the type of encipherment used, a time-date stamp, the version of IPS employed, cryptographic chaining information and a key verification field, but it contains no encrypted key field, since IPS uses only a 1-level key management system.

Additional security systems are described in United States Patent Nos. 4,238,854, 4,757,533, 5,150,407, 5,235,641, 5,495,533, 5,563,946, 5,699,428, 5,719,941, 5,751,841, 5,787,169, 5,841,871, 6,011,847 and 6,023,506.

### Summary of the Invention

Embodiments of the present invention include methods, systems and computer program products which provide for controlling access to digital data in a file by obtaining a passphrase from a user and generating a personal key based on the obtained

passphrase. A file encryption key is generated and the digital data in the file encrypted with the file encryption key to provide an encrypted file. The file encryption key is encrypted with the personal key to provide an encrypted file encryption key. A file header containing the encrypted file encryption key is created and associated with the encrypted file. The encrypted file and the file header associated with the encrypted file may be stored at a file server.

In further embodiments of the present invention, the passphrase comprises a current passphrase and may be changed to a new passphrase. The file header associated with the encrypted file is retrieved from the file server and the personal key is generated from the current passphrase associated with the file. The encrypted file encryption key is decrypted with the personal key to provide a recovered file encryption key. A new personal key is generated based on the new passphrase and the file encryption key encrypted with the new personal key to provide a new encrypted file encryption key. A new file header containing the new encrypted file encryption key is generated, associated with the file and stored at the file server. In further embodiments, a plurality of files may utilize the same passphrase and one or more of the plurality of files may have their passphrases changed to the new passphrase. In particular embodiments, all files stored at the file server associated with a user and having a file header with an encrypted file encryption key encrypted with a personal key derived from the current passphrase may be changed to the new passphrase.

In further embodiments, the file may be decrypted by obtaining a passphrase to be utilized in decrypting the file. The encrypted file and the associated file

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header are retrieved from the file server. The personal key is generated from the passphrase to be utilized in decrypting the file and the encrypted file encryption key decrypted with the personal key to provide a recovered file encryption key. The file may then be decrypted with the recovered file encryption key.

In still further embodiments of the present invention, a user identification associated with an owner of the file is obtained. A file identification associated with the file is also obtained. In such embodiments, a personal key based on the obtained passphrase may be generated by hashing the user identification, the passphrase and the file identification to provide the personal key.

Furthermore, the file and the file header may be selectively stored at the file server based on a type of store requested by the user and an evaluation of whether an existing file and file header having the user identification and file identification are stored at the file server.

In still further embodiments of the present invention, an integrity key is generated. A message authentication code is generated based on digital data of the file utilizing the integrity key. The file encryption key and the integrity key are encrypted with the personal key to provide encrypted file encryption keys. The file header containing the encrypted file encryption key is created containing the encrypted file encryption keys and the message authentication code.

To decrypt the file a passphrase to be utilized in decrypting the file is obtained. The encrypted file and the associated file header are retrieved from the file server. The personal key is generated from the passphrase to be utilized in decrypting the file. The

encrypted file encryption keys are decrypted with the personal key to provide a recovered file encryption key and a recovered integrity key and the file decrypted with the recovered file encryption key. The recovered integrity key is hashed with the decrypted file to provide a recovered message authentication code which is compared with a message authentication code from the file header to confirm that the decrypted file corresponds to the file which generated the message authentication code from the file header.

Furthermore, the file encryption key may be hashed with the integrity key to provide a verification value. The file encryption key, the integrity key and the verification value are then encrypted with the personal key to provide the encrypted file encryption keys. Decryption of the file may then further include hashing the recovered file encryption key and the recovered integrity key to provide a hash value. The hash value and the recovered verification value may be compared and the file decrypted with the recovered file encryption key if the comparison of the hash value and the recovered verification value indicates that the values are equal.

In additional embodiments of the present invention, it may be determined if a party other than an owner of the file is to have access to the file. A public key associated with the party other than the owner of the file is obtained and the file encryption key encrypted with the public key of the party other than the owner of the file to provide a public key encrypted file encryption key. The public key encrypted file encryption key may be incorporated in the header associated with the file if the party other than the owner of the file is to have access to the file.

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In such embodiments, the file may be decrypted by retrieving the file and the file header from the file server and obtaining a private key associated with the public key. The public key encrypted file encryption key is decrypted with the private key to provide the file encryption key and the file decrypted with the file encryption key. In further embodiments, an integrity key may be generated and a message authentication code generated based on digital data of the file utilizing the integrity key. The file encryption key and the integrity key are encrypted with the public key to provide encrypted file encryption keys and a file header containing the encrypted file encryption keys and the message authentication code created. The integrity key and the file encryption key may also be hashed to provide an verification value which may also be encrypted with the public key and incorporated in the file header.

Furthermore, the public key may be changed by retrieving the file header, decrypting the file encryption keys with the personal key and re-encrypting the decrypted keys with the new public key.

While the invention has been described above primarily with respect to the method aspects of the invention, both systems and/or computer program products are also provided.

#### Brief Description of the Drawings

**Figure 1** is a block diagram of a system for encrypted file access according to embodiments of the present invention;

**Figure 2** is a block diagram of data processing systems according to embodiments of the present invention;



Figure 3 is a more detailed block diagram of data processing systems according to embodiments of the present invention;

Figure 4 is a block diagram of a file and file header according to embodiments of the present invention;

Figure 5 is a flowchart illustrating operations of a client of an owner of a file for creating or updating an encrypted file according to embodiments of the present invention;

Figure 6 is a flowchart illustrating operations of a server for creating or updating an encrypted file according to embodiments of the present invention;

Figure 7 is a flowchart illustrating operations of a client of an owner of a file for retrieving an encrypted file according to embodiments of the present invention;

Figure 8 is a flowchart illustrating operations of a server for retrieving an encrypted file according to embodiments of the present invention;

Figure 9 is a flowchart illustrating operations of a client of a trusted third party associated with a file for retrieving an encrypted file according to embodiments of the present invention;

Figure 10 is a flowchart illustrating operations of a client of an owner of a file for changing a password or passphrase associated with an encrypted file according to embodiments of the present invention;

Figure 11 is a flowchart illustrating operations of a server for changing a password or passphrase associated with an encrypted file according to embodiments of the present invention; and

Figure 12 is a flowchart illustrating operations of a client of an owner of a file for changing a public

key of a trusted third party associated with an encrypted file according to embodiments of the present invention.

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### Detailed Description of Preferred Embodiments

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

As will be appreciated by one of skill in the art, the present invention may be embodied as a method, data processing system, or computer program product. Accordingly, the present invention may take the form of an entirely hardware embodiment, an entirely software embodiment or an embodiment combining software and hardware aspects. Furthermore, the present invention may take the form of a computer program product on a computer-usable storage medium having computer-usable program code means embodied in the medium. Any suitable computer readable medium may be utilized including hard disks, CD-ROMs, optical storage devices, a transmission media such as those supporting the Internet or an intranet, or magnetic storage devices.

Computer program code for carrying out operations of the present invention may be written in an object oriented programming language such as Java®, Smalltalk or C++. However, the computer program code for carrying out operations of the present invention may also be

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written in conventional procedural programming languages, such as the "C" programming language. The program code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer. In the latter scenario, the remote computer may be connected to the user's computer through a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

The present invention is described below with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems) and computer program products according to embodiments of the invention. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions specified in the flowchart and/or block diagram block or blocks.

These computer program instructions may also be stored in a computer-readable memory that can direct a computer or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer-readable memory produce an article of manufacture including instruction

means which implement the function specified in the flowchart and/or block diagram block or blocks.

The computer program instructions may also be loaded onto a computer or other programmable data processing apparatus to cause a series of operational steps to be performed on the computer or other programmable apparatus to produce a computer implemented process such that the instructions which execute on the computer or other programmable apparatus provide steps for implementing the functions specified in the flowchart and/or block diagram block or blocks.

As is described in more detail below, the present invention may provide for secure access to an encrypted file utilizing two-level encryption where a file is encrypted with a first key and where that key is encrypted with a second key generated from a password or passphrase associated with the file. As used herein, the terms password and passphrase are used interchangeably to refer to a value or sequence of values which may be provided by a user. The encrypted key may be stored in a header associated with the file and maintained on a server for access by a user. Additional embodiments of the present invention provide for storing, updating, retrieving and managing keys associated with users which have access to the file. Various embodiments of the present invention will now be described with reference to **Figures 1** through **12**.

Referring now to **Figure 1**, a system for secure access to encrypted data according to embodiments of the present invention is illustrated. As seen in **Figure 1**, a file server **102**, which may store encrypted files and encrypted headers associated with the files, has access to a network **104**. The network **104** may be an intranet, an extranet, a virtual private network, the Internet, a wireless network, a direct dial connection

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or even a "sneaker" network where information is transmitted from processing system to processing system utilizing a removable storage media. Whatever the method of communication, the network 104 serves to provide communication between the file server 102 and client data processing systems 106 and 106' which may access the encrypted files and headers on the file server 102. As used herein, the terms client data processing system and client may be used interchangeably.

While systems according to embodiments of the present invention are illustrated as having a separate file server 102 and client data processing systems 106 and 106', as will be appreciated by those of skill in the art, such functions may be integrated into a single data processing system or may be distributed across multiple data processing systems. Furthermore, multiple file servers 102 may be accessed by a single or multiple client data processing systems 106 and 106'. Additionally, while not illustrated in **Figure 1**, multiple data processing systems may access one or more of the file server(s) 102 through one or more client data processing systems 106 and 106'. Thus, the client data processing systems 106 and 106' may act as servers and provide files to other data processing systems. Such a system may be beneficial where the file server 102 communicates with the client data processing systems 106 and 106' over an insecure network but where the other data processing systems may communicate with the client data processing systems 106 and 106' over a secure network, through a direct connection or through other such trusted communication media. In such a system, the client data processing systems 106 and 106' may act as a gateway between the trusted communication

media and the insecure network. Thus, the present invention should not be construed as limited to the particular configuration illustrated in **Figure 1** but may be utilized with any configuration suitable for carrying out the operations described herein.

Referring now to **Figure 2**, an exemplary embodiment of a data processing system **230** suitable for use as either a file server **102** or a client data processing system **106** and/or **106'** in accordance with embodiments of the present invention is illustrated and may include input device(s) **232** such as a keyboard or keypad, a display **234**, and a memory **236** that communicate with a processor **238**. The data processing system **230** may further include a storage system **242**, a speaker **244** and an I/O data port(s) **246** that also communicate with the processor **238**. The storage system **242** may include removable and/or fixed media such as floppy disks, ZIP drives, hard disks or the like as well as virtual storage such as a RAMDISK. The I/O data port **246** can be used to transfer information between the data processing system **230** and another computer system or a network (e.g., the Internet). Such data processing systems may include, for example, personal computers, laptop computers, mainframe computers, pervasive computing devices such as personal digital assistants, smartphones or the like, or even embedded processing systems. The components of a particular data processing system may be conventional or custom components, such as those used in many conventional computing devices, which may be configured to operate as described herein.

**Figure 3** is a block diagram of data processing systems that illustrate systems, methods, and computer program products in accordance with embodiments of the

present invention. The processor 238 communicates with the memory 236 via an address/data bus 248. The processor 238 can be a commercially available or custom microprocessor. The memory 236 is representative of the overall hierarchy of memory devices containing the software and data used to implement the functionality of the data processing system 230. The memory 236 can include, but is not limited to, the following types of devices: cache, ROM, PROM, EPROM, EEPROM, flash memory, SRAM, and DRAM.

As shown in Figure 3, the memory 236 may contain several categories of software and data used in the data processing system 230: the operating system 252; the application program(s) 10; the input/output (I/O) device drivers 258; and the data 256. As will be appreciated by those of skill in the art, the operating system 252 may be any operating system suitable for use with a data processing system, such as OS/2, AIX or OS/390 from International Business Machines Corporation, Armonk, NY, WindowsCE, WindowsNT, Windows95, Windows98 or Windows2000 from Microsoft Corporation, Redmond, WA, PalmOS from Palm, Inc., MacOS from Apple Computer, UNIX or Linux, proprietary operating systems or dedicated operating systems, for example, for embedded data processing systems.

The I/O device drivers 258 typically include software routines accessed through the operating system 252 by the application program 10 to communicate with devices such as the input devices 232, the display 234, the speaker 244, the storage system 242, the I/O data port(s) 246, and certain memory 236 components. The application program(s) 10 is illustrative of the programs that implement the various features of the data processing system 230. Finally, the data 256

represents the static and dynamic data used by the application program(s) 10, operating system 252, I/O device drivers 258, and other software programs that may reside in the memory 236.

As is further seen in **Figure 3**, for client processing systems, the application program(s) 10 preferably includes a personal key client 12. The personal key client 12 may function as described herein for providing access to encrypted files. For server data processing systems, the application program 10 may, instead, include a file server module (not shown) which may store and control access to encrypted files and encrypted file headers as described herein.

While the present invention is illustrated, for example, with reference to a personal key client 12 and a file server which carries out the operations for software installation, as will be appreciated by those of skill in the art, the functions carried out by these modules may also be incorporated into for example, the operating system 252. Thus, the present invention should not be construed as limited to the configuration of **Figure 3** but is intended to encompass any configuration capable of carrying out the operations described herein.

As briefly described above, in embodiments of the present invention, an encrypted file and an encrypted file header are associated with each other. **Figure 4** illustrates such an arrangement. As seen in **Figure 4**, an encrypted file 400 may be a file which was encrypted with an encryption key  $ke$  and is illustrated in **Figure 4** as  $ENC_{ke}(\text{file})$ . An encrypted file header 402 is also provided. The file header 402 may contain both encrypted and unencrypted portions. As illustrated in **Figure 4**, the file header may contain the tuple  $(id,$



fid) 404 where *id* is a user identification of an owner of the file and *fid* is a file identification associated with the file.

A file encryption key is stored in the file header 402 encrypted under a personal key *k* belonging to the user, derived from a user-supplied "passphrase/password." Such an encrypted file encryption key 406 is illustrated as  $Enc_k(ke, ki, hash(ke, ki))$  in Figure 4. The file encryption key may also be encrypted with a public key or keys *pk* of one or more trusted third parties and incorporated in the file header 402 so as to allow third parties access to the file contents. Such an encrypted file encryption key 410 is illustrated as  $Enc_{pk}(ke, ki, hash(ke, ki))$  in Figure 4. A message authentication code (MAC) 408 may also be included within the file header 402 to verify the authenticity of the file after decryption. Therefore, a file can be decrypted by the user who created the encrypted file, and who has the "passphrase" needed to decrypt the file, and/or by a trusted third party that the creating-user has granted access to the file.

Embodiments of the present invention may provide a suitable file encryption solution, with relatively few components, at a correspondingly small cost, while at the same time being designed in such a way that additional system components can be layered "on top" of embodiments of the present invention, to provide enhanced user authentication with the capability for greater granularity of access control. Such additional enhancements are described in detail in commonly assigned and concurrently filed United States Patent Application Serial No. \_\_\_\_\_, entitled "SECURE DATA STORAGE AND RETRIEVAL WITH KEY MANAGEMENT AND USER



a request to the file server to store a file under a duplicate tuple  $(id, fid)$ , thereby possibly causing duplicate files to be stored under the same tuple  $(id, fid)$ . In addition, an adversary could cause unauthorized files to be stored under another user's  $id$ .

As is described in more detail below, for data protection, each user selects a "password" or "passphrase" denoted by pw. The password may be considered to be a secret value that only the user knows. The user password/passphrase is not stored by the system. As is further described below, the user may change their password/passphrase.

As described above, systems for user data storage and retrieval according to the present invention may be embodied as a personal key client resident in the user's personal computer and a file server where encrypted files are maintained within the system. Operations of the personal key client and the file server will now be described with reference to **Figures 5 through 12.**

The operations for file management illustrated in **Figures 5 through 12** may provide core functions which provide for the control of encrypted files. Thus, as will be appreciated by those of skill in the art in light of the present disclosure, these core functions may be further manipulated to provide additional file management functions. For example, a rename file operation could be associated with a file by retrieving the file and storing the file with the new file name. Optionally, the old file could be overwritten, deleted, or marked as inaccessible. Similarly, third party access to files and file ownership may be changed through the retrieval, storage and password or key

change operations. Thus, for example, to change which users are trusted third party's, the public key operations described below could be utilized to replace one third parties public key with another's and, thereby, provide access to file to a different third party. Similarly, file ownership could be changed by allowing the new owner third party access to the file, the new owner could retrieve the file and store the file under a new tuple (*id*, *fid*) and, thereby, obtain ownership of the file. Thus, the core functions described herein may provide a robust feature set which may be readily expanded through combinations of operations. Furthermore, additional "file management" functions could also be incorporated, for example, utilizing conventional file server operations.

Data storage operations according to embodiments of the present invention will now be described with reference to **Figures 5** and **6**. **Figure 5** illustrates operations of a personal key client for data storage. **Figure 6** illustrates operations of the file server for data storage.

As seen in **Figure 5**, when a user wants to encrypt a file and store the encrypted file on the file server, the user submits their *userid* (*id*) and password/passphrase (*pw*) to the personal key client (block **500**). The user (or the personal key client) may pick a unique *fileid* (i.e., *fid*) for the file to be stored on the file server (block **502**). The *fileid* may be based on a file name provided by the user. For example, the *fileid* may be the file name or may be generated from the file name.

The personal key client generates a key encrypting key *k* (block **504**) based on the password/passphrase provided by the user. The key encrypting key *k* may be

generated utilizing any suitable key generation technique, for example, the key may be generated as follows:

$k = \text{Hash}(id, pw, fid)$

5 The "Hash" function used here can be any strong collision-resistant one-way hash function such as SHA-1.

10 The personal key client also generates a random encryption key  $ke$  for encrypting the content of the file (block 506). Optionally, the personal key client generates a random integrity protection key  $ki$  for providing integrity protection on the content of the file (block 506). The encryption key  $ke$  and the integrity key  $ki$  may be generated utilizing any  
15 suitable random key generation technique. Such techniques are known to those of skill in the art and, therefore, will not be described further herein.

20 The personal key client encrypts  $ke$ , and, optionally,  $ki$  and a hash of  $ke$ ,  $ki$  with  $k$  using, for example, a symmetric-key encryption algorithm (such as DES, Triple-DES, RC5, etc) (block 508). That is,

$\text{Enc}_k(ke, ki, \text{Hash}(ke, ki)).$

25 The hash of  $ke$ ,  $ki$  provides a verification value which may provide a way to do an integrity check on  $ke$  and  $ki$  when decrypted. The "Hash" function used here can be any strong collision-resistant one-way hash function such as SHA-1.

30 As is further illustrated in **Figure 5**, optionally, the user may have the option to enable "file recovery by a trusted third party" in case, for example, they forget their password or if the file must be recoverable by a trusted third party. When this option is selected (block 510), the personal key client provides the public key ( $pk$ ) of a trusted third party.

Only the trusted third party with the corresponding secret key ( $sk$ ) can decrypt any data encrypted with  $pk$ . When the "file recovery by a trusted third party" option is selected (block 510), the client encrypts  $ke$ , and optionally,  $ki$  and a hash of  $ke$ ,  $ki$  with  $pk$ , for example, using an asymmetric-key encryption algorithm (such as RSA, Elliptic curve, etc) (block 512). That is,

$Enc_{pk}(ke, ki, Hash(ke, ki))$ .

As described above, the hash of  $ke$ ,  $ki$  provides a way to do an integrity check on  $ke$  and  $ki$  when decrypted.

As a further option, the personal key client may generate a MAC (message authentication code) on the unencrypted content of the file (block 514). For example, the personal key client may utilize  $ki$  and a strong collision-resistant one-way hash function such as SHA-1 to generate the MAC. That is,  $MAC = Hash(file, ki)$ . The personal key client may choose to split the file into pieces (e.g.,  $piece_1$ ,  $piece_2$ , ...) and compute the MAC for each piece individually. This allows data recovery to be done in pieces which may be useful for audio or video applications when data streaming is used.

The personal key client prepares a file header, which may contain, among other things, the applicable values ( $id$ ,  $fid$ ),  $Enc_k(ke, ki, Hash(ke, ki))$ , MAC, and  $Enc_{pk}(ke, ki, Hash(ke, ki))$  (block 516) if provided in a particular embodiment. The personal key client also encrypts the content of the file with  $ke$  using a symmetric-key encryption algorithm (such as DES, Triple-DES, RC5, etc) (block 518). That is,  $Enc_{ke}(file)$ . Again, the personal key client may choose to split the file into pieces (e.g.,  $piece_1$ ,  $piece_2$ , ...) and encrypt each piece individually. This may allow data recovery

to be done in pieces which may be useful for audio or video applications when data streaming is used.

The personal key client next associates the file header with the encrypted file (block 520). The header associated with each file preferably accompanies the file in case the file is moved or renamed or backed-up. The header may be associated with the file in a number of ways. For example, the header may be stored as the first few bytes of the file, as a trailer at the end of the file, in the file's directory entry, in a separate area associated with the file's directory entry, in a local database or combinations thereof.

The personal key client determines if the type of storage operation, e.g., whether the operation is an update or the creation of a new file (block 522) and sends a "store new encrypted file" request (block 526) or a "store updated encrypted file" request (block 524) to the file server that includes the encrypted file,  $Enc_{k_e}(\text{file})$ , and the file header. A "store new encrypted file" request indicates that the encrypted file is a new file to be stored under the tuple  $(id, fid)$ , whereas a "store updated encrypted file" request indicates that the encrypted file is intended to replace an existing file currently stored under the tuple  $(id, fid)$ . In either case, the personal key client waits for confirmation of the store request (block 528).

Turning now to **Figure 6**, the operations of the file server may begin when the file server receives either the "store new encrypted file" or the "store updated encrypted file" requests (block 600). If a "store new encrypted file" request is received (block 602), the file server verifies that no directory entry exists for the tuple  $(id, fid)$  received in the "store

new encrypted file" request (block 610). If no such directory entry exists, the file server creates a new file directory entry, it stores the file header in accordance with a predetermined one of the

5      aforementioned techniques for associating the file header with the encrypted file, and it stores the received encrypted file in its database (block 612). Otherwise, the "store new encrypted file" request is rejected and a rejected response is sent to the client

10     (block 614).

If a "store updated encrypted file" request is received (block 602), the file server verifies that a directory entry exists for the tuple (id, fid) received in the "store updated encrypted file" request (block 604). If such a directory entry exists, the file server replaces the current file header with the received file header, and it replaces the current encrypted file with the received encrypted file (block 606). Otherwise, the "store updated encrypted file" request is rejected and a rejected response sent to the client (block 614).

If, however, either of the store operations are successful, the file server sends a response message to the personal key client indicating that the "store new encrypted file" or "store updated encrypted file request has been honored (block 608).

Returning to **Figure 5**, when the personal key client receives the response from the file server (block **528**), the personal key client deletes all the information associated with this file encryption operation from its memory/storage (i.e., keys, password/passphrase, encrypted information) (block **530**). If the method for associating the file header with the encrypted file calls for the file header to be



stored locally, in a local database, then the file header is so stored and only the working copy of the file header is deleted from its memory/storage. The nature of the response from the file server may also, optionally, be reported to the user.

Operations for data retrieval will now be described with reference to **Figures 7** through **9**. **Figure 7** illustrates operations of the personal key client for data retrieval by the file owner. **Figure 8** illustrates operations of the file server for data retrieval by the file owner or by a trusted third party. **Figure 9** illustrates operations for data retrieval by a trusted third party. As seen in **Figures 7** through **9**, a file stored on a file server may be retrieved and recovered by a user with access rights such as the file owner or a trusted third party. Note that a trusted third party can only recover the file if the "file recovery by a trusted third party" option was selected when the file was stored on the file server.

Turning to **Figure 7**, when a user wants to retrieve and decrypt a file stored on the file server, the user submits their userid (*id*) and password/passphrase (*pw*) to the personal key client (block **650**). The user also requests access to a named file (corresponding to a *fid*) stored on the file server (block **652**) by, for example, either specifying a file name or a fileid. If a file name is specified, the personal key client maps the named file to a file ID (*fid*) (block **654**). In either case, the personal key client sends an "access encrypted file" request, along with the tuple (*id*, *fid*), to the file server (block **656**). The personal key client then waits to receive the response to the request from the file server.



correctly, the personal key client decrypts the encrypted file  $Enc_{ke}(file)$  with  $ke$  (block 670). That is,

$file = Dec_{ke}(Enc_{ke}(file))$ .

- 5 If the hash values are not equal, then an error has occurred and the error may be reported to the user (block 680). Operations would then terminate.

If a MAC is incorporated in the file header, then operations of blocks 672 through 676 may be performed.

- 10 The personal key client generates a MAC (message authentication code) on the decrypted content of the file with  $ki$  (block 672). For example, the MAC may be generated by determining,

$MAC = Hash(file, ki)$ .

- 15 The personal key client checks to see if the MAC that it generated is equal to the MAC that it received in the file header from the file server (block 676). If they are equal, then the file is recovered correctly and its content has not been changed and the contents may be provided to the user (block 678). If the MAC values are not equal, then an error has occurred, the error may be reported to the user (block 680) and operations may terminate.

- Turning to **Figure 9**, operations for data retrieval by a trusted third party are illustrated. When the trusted third party wants to retrieve and recover a file ( $fid$ ) associated with a  $userid$   $id$ , the trusted third party requests access to a named file (corresponding to a  $fid$ ) stored on the file server belonging to the file owner whose  $userid$  is  $id$  by providing, for example, the name of the file to retrieve (block 700) and, possibly, the  $id$  of the owner of the file. The personal key client maps the named file to a file ID ( $fid$ ) (block 702) and creates the

tuple (*id*, *fid*). The *userid* utilized to create the tuple may be obtained from the trusted third party or may be stored by the personal key client or the file server. In any event, the personal key client sends an  
5 "access encrypted file for trusted third party" request, along with the tuple (*id*, *fid*), to the file server (block 704). Operations of the file server in response to the "access encrypted file for trusted third party request" are the same as those illustrated  
10 in **Figure 8** and described above with reference to access by the file owner.

When the personal key client receives the response from the file server, if the response is negative, operations of **Figure 8** may terminate at block 704 and,  
15 optionally, the error may be reported to the user. However, if the response provides the encrypted file and file header, the personal key client extracts the encrypted value associated with the trusted third party from the header (block 708), for example,  $Enc_{pk}(ke, ki, Hash(ke, ki))$ . The extracted encrypted value is  
20 decrypted with the trusted third party's private key *sk* to recover the encryption key utilized to encrypt the file (block 710). For example, in the embodiment illustrated in **Figure 9**, the values *ke*, *ki* and  
25  $Hash(ke, ki)$  may be recovered. That is, *ke*, *ki*,  $Hash(ke, ki) = Dec_{sk}(Enc_{pk}(ke, ki, Hash(ke, ki)))$ .

If a hash value is provided, the personal key client computes  $Hash(ke, ki)$  on the decrypted *ke*, *ki* (block 712) and compares the result with the decrypted  
30 value of  $Hash(ke, ki)$  to see if they are equal (block 714). If the hash values are equal, then *ke* and *ki* are recovered correctly and they have not been changed. The personal key client may then decrypt the encrypted file  $Enc_{ke}(file)$  with *ke* (block 716). That is,

file = Dec<sub>ke</sub>(Enc<sub>ke</sub>(file)).

If the hash values are not equal (block 714), then an error has occurred and this error may, optionally, be reported to the user (block 726) and operations may terminate.

If a MAC is provided in the file header, then the operations of blocks 718 through 722 of Figure 9 may be performed. The personal key client generates a MAC (message authentication code) on the unencrypted content of the file with  $k_i$  (block 718). That is,

MAC = Hash(file,  $k_i$ ).

The personal key client extracts the MAC from the file header (block 720) and determines if the MAC that it generated is equal to the MAC that it received in the file header from the file server (block 722). If they are equal, then the file is recovered correctly and its content has not been changed. The contents are then provided to the user (block 724). If the MAC values are not equal (block 722), then an error has occurred and this error may, optionally, be reported to the user (block 726) and operations may terminate.

Figures 10, 11 and 12 illustrate operations for changing a password or passphrase for a file and for changing the public key of a trusted third party.

Figure 10 illustrates operations carried out by a personal key client to change a password for a file or files. Figure 11 illustrates operations of a file server for changing the password/passphrase or the public key of a trusted third party for a file or files. Figure 12 illustrates operations of a personal key client for changing the public key of a trusted third party.

Turning to Figure 10, when the user wants to change their current (i.e., old) password/passphrase pw

to a "new password/passphrase" *new\_pw*, the personal key client obtains the user's *userid* (*id*), current password/passphrase (*pw*), and new password/passphrase (*new\_pw*) (block 750) by, for example, the user submitting it to the personal key client. The user may also request a password/passphrase change and may specify which file or files are to be changed. Such a specification may be provided by providing the file name or names, *fileid* or *fileids*, by providing a wildcard, such as "\*", or combination of wildcards, such as "?", and partial file name or *fileids* which may be utilized as a criteria for selecting the files for which password changes are to be applied. For example, if the wildcard "\*" is specified, all files for a given user will have the password changed. Alternatively, because the key for a given file is based on the files password, the "\*" designator could change the password for all files with the password *pw*. In any event, the personal key client sends an "access file headers" request along with the tuple defining the *userid* and the *fileids*, for example, (*id*, \*), to the file server (block 752).

As illustrated in **Figure 11**, in response to the "access file headers" request (block 800), the file server responds by obtaining the file headers corresponding to the provided tuple, for example, (*id*, \*) (block 802). The file server sends the obtained file headers to the personal key client (block 804) and the file server waits for a response from the personal key client (block 806).

Returning to **Figure 10**, the personal key client receives the file header(s) from the file server (block 754) and obtains one of the file headers for processing (block 756). The personal key client extracts the tuple

(*id*, *fid*) from the file header (block 758) and generates the key encrypting key *k* (block 760). That is,

$k = \text{Hash}(id, pw, fid).$

5 The personal key client also extracts the encrypted value encrypted with *k* from the file header (block 762), for example,  $\text{Enc}_k(ke, ki, \text{Hash}(ke, ki))$ , and decrypts the encrypted value with *k* (block 762) to recover the encryption key(s), such as *ke*, *ki* and  
10  $\text{Hash}(ke, ki)$ . That is,  $ke, ki, \text{Hash}(ke, ki) = \text{Dec}_k(\text{Enc}_k(ke, ki, \text{Hash}(ke, ki)))$ .

If a hash value is present in the encrypted value, the personal key client also computes  $\text{Hash}(ke, ki)$  using the decrypted *ke*, *ki* (block 764) and compares the  
15 computed hash value with the decrypted  $\text{Hash}(ke, ki)$  to determine if they are equal (block 766). If they are equal, then *ke* and *ki* are recovered correctly and they have not been changed. If they are not equal, then processing of the current header is concluded and, if  
20 more headers are available for processing (block 774), a next header is obtained (block 756) and processing begins again with block 758. Such an error may also generate a message to a user so as to indicate that the password of the file associated with the file header  
25 was not changed and/or that an error occurred processing the header file.

If the hash values are equal, the personal key client generates the new key encrypting key *new\_k* (block 768). That is,

30  $new\_k = \text{Hash}(id, new\_pw, fid).$

The personal key client encrypts the key values, for example, *ke*, *ki* and  $\text{Hash}(ke, ki)$ , with *new\_k* (block 770). That is,

$\text{Enc}_{new\_k}(ke, ki, \text{Hash}(ke, ki)).$

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The personal key client replaces the current value of the encrypted keys, such as  $Enc_k(ke, ki, Hash(ke, ki))$ , in the file header with the new value  $Enc_{new,k}(ke, ki, Hash(ke, ki))$  (block 772). At this point, the personal

5 key client may continue processing additional file headers if any remain (block 774).

If no more file headers remain (block 774), the personal key client sends a "store updated file headers" request to the file server, along with the

10 updated file headers (block 776). The personal key client then waits for a response from the file server (block 778).

Returning to **Figure 11**, in response to the "store updated file headers" request (block 806), the file

15 server replaces the appropriate existing file headers with the received new file headers (block 808). If the replacement of file headers was successful (block 810), the file server sends a response message to the personal key client indicating that the file headers

20 have been replaced in the file server's database (block 812). If the replacement is not successful, the file server may respond by rejecting the request and sending a "rejected" response to the personal key client (block 814). Examples of situations which would result in

25 rejection of an "update file headers" request may include a request to update a file header which does not exist or which has been "locked" by the file server.

In any event, when the personal key client

30 receives the response from the file server, operations continue at block 780 of **Figure 10**. The personal key client removes all unneeded copies of the file headers from its memory. As with the systems described above, if the file headers are maintained locally, this may



involve removing the file headers from working memory. Thus, at block 780, the personal key client deletes all the information associated with this password/passphrase change operation from its memory/storage (i.e., keys, password/passphrase, encrypted information).

**Figure 11** illustrates operations for changing the public key of a trusted third party. The user or personal key client may be informed when the trusted third party changes its public key. For example a server may send a new certificate, containing the new public key, to the user or personal key client. Alternatively, as noted above, these procedures may be utilized to change the third party which is trusted. Thus, for example, if an employee leaves a company, a new trusted third party could be designated by replacing the public key of the former employee with that of a new employee.

However the notification of a change in a public key occurs, the operations of **Figure 12** may be carried out when the public key of a trusted third party is to be changed from a current (i.e., old) public key *pk* to a "new public key" *new\_pk*. As seen in **Figure 12**, the personal key client obtains a userid (*id*), current password/passphrase (*pw*), fileid(s) and new public key *new\_pk* (block 850). Such information may be obtained by the user providing some or all of the information to the personal key client and indicating that a public key update is to be performed. As described above, the files for which the public key update may be performed may be specified in any of the various ways described above. The personal key client sends an "access file headers" request along with the tuple, for example, (*id*, \*), to the file server (block 852) and waits to



$Enc_{new\_pk}(ke, ki, Hash(ke, ki))$ .

The personal key client replaces the current value of the encrypted keys, such as  $Enc_{pk}(ke, ki, Hash(ke, ki))$ , in the file header with the new value of the encrypted keys, such as,  $Enc_{new\_pk}(ke, ki, Hash(ke, ki))$  (block 870). If there are more headers to process (block 872), then a next header is obtained (block 856) and processing continues at block 858.

If there are no more headers to process, the personal key client sends a "store updated file headers" request to the file server, along with the updated file headers (block 874). Operations of the file server are carried out as described above with reference to **Figure 11** and the personal key client waits for a response from the file server (block 876). When the personal key client receives the response from the file server, operations continue at block 878 of **Figure 12**. The personal key client removes all unneeded copies of the file headers from its memory. As with the systems described above, if the file headers are maintained locally, this may involve removing the file headers from working memory. Thus, at block 878, the personal key client deletes all the information associated with this password/passphrase change operation from its memory/storage (i.e., keys, password/passphrase, encrypted information).

While the operations of **Figures 10, 11 and 12** are illustrated as being performed in a batch operation, such operations could also be performed on a header by header basis. In such embodiments, the each header to be changed could be obtained, modified and then stored on the file server. Thus, the present invention should not be construed as limited to the particular operations illustrated in **Figures 10 through 12**.

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The flowcharts and block diagrams of **Figures 1** through **12** illustrate the architecture, functionality, and operation of possible implementations of systems, methods and computer program products for securing stored digital data. In this regard, each block in the flow charts or block diagrams represents a module, segment, or portion of code, which comprises one or more executable instructions for implementing the specified logical function(s). It should also be noted that in some alternative implementations, the functions noted in the blocks may occur out of the order noted in the figures. For example, two blocks shown in succession may in fact be executed substantially concurrently or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved.

In the drawings and specification, there have been disclosed typical preferred embodiments of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention being set forth in the following claims.

THAT WHICH IS CLAIMED:

1. A method of controlling access to digital data in a file comprising:  
obtaining a passphrase from a user;  
generating a personal key based on the obtained  
5 passphrase;  
generating a file encryption key;  
encrypting the digital data in the file with the file encryption key to provide an encrypted file;  
encrypting the file encryption key with the  
10 personal key to provide an encrypted file encryption key;  
creating a file header containing the encrypted file encryption key; and  
associating the file header with the encrypted  
15 file.

2. A method according to Claim 1, further comprising the step of storing the encrypted file at a file server.

3. A method according to Claim 2, wherein the passphrase comprises a current passphrase and wherein the step of storing the encrypted file is followed by  
5 the steps of:  
obtaining the file header associated with the encrypted file stored at the file server;  
generating the personal key from the current passphrase associated with the file;  
10 decrypting the encrypted file encryption key with the personal key to provide a recovered file encryption key;  
generating a new personal key based on a new passphrase;

15           encrypting the file encryption key with the new  
personal key to provide a new encrypted file encryption  
key;

          creating a new file header containing the new  
encrypted file encryption key; and  
20           associating the new file header with the encrypted  
file stored at the file server.

4.   A method according to Claim 3, further  
comprising the step of storing the new file header  
associated with the encrypted file at the file server.

5           5.   A method according to Claim 4, wherein a  
plurality of files have corresponding associated file  
headers containing encrypted file encryption keys  
encrypted with a corresponding plurality of personal  
keys based on the passphrase, and wherein the step of  
obtaining the file header associated with the encrypted  
file comprises the step of retrieving the plurality of  
file headers associated with the encrypted files from  
the file server;

10           wherein the step of generating the personal key  
from the current passphrase associated with the file  
comprises the step of generating the plurality of  
personal keys from the current passphrase associated  
with the plurality of files;

15           wherein the step of decrypting the encrypted file  
encryption key with the personal key to provide a  
recovered file encryption key comprises the step of  
decrypting the plurality of encrypted file encryption  
keys with corresponding ones of the plurality of  
20           personal keys to provide a corresponding plurality of  
file encryption keys;

          wherein the step of generating a new personal key  
based on the new passphrase comprises the step of

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25 generating a plurality of new personal keys based on  
the new passphrase;  
wherein the step of encrypting the file encryption  
key with the new personal key to provide a new  
encrypted file encryption key comprises the step of  
30 encrypting the plurality of file encryption keys with  
corresponding ones of the plurality of new personal  
keys to provide a plurality of new encrypted file  
encryption keys;  
wherein the step of creating a new file header  
containing the new encrypted file encryption key  
35 comprises the step of creating a plurality of new file  
headers containing the new encrypted file encryption  
keys; and  
wherein the step of storing the new file header  
associated with the file at the file server comprises  
40 the step of storing the plurality of new file headers  
associated with the plurality of files at the file  
server.

6. A method according to Claim 5, wherein the  
plurality of files comprise all files stored at the  
file server associated with a user and having a file  
header with an encrypted file encryption key encrypted  
5 with a personal key derived from the current  
passphrase.

7. A method according to Claim 2, wherein the  
step of storing the encrypted file is followed by the  
steps of:  
obtaining a passphrase to be utilized in  
5 decrypting the file;  
retrieving the encrypted file and the associated  
file header;

generating the personal key from the passphrase to be utilized in decrypting the file;

10        decrypting the encrypted file encryption key with the personal key to provide a recovered file encryption key; and

         decrypting the file with the recovered file encryption key.

8.    A method according to Claim 1, further comprising the steps of:

         obtaining a user identification associated with an owner of the file;

5        obtaining a file identification associated with the file; and

10        wherein the step of generating a personal key based on the obtained passphrase comprises the step of hashing the user identification, the passphrase and the file identification to provide the personal key.

9.    A method according to Claim 8, further comprising the step of storing the file and the associated file header at a file server.

10.   A method according to Claim 9, wherein the step of storing the file and the associated file header at a file server comprises the step of selectively  
5        storing the file and the file header based on a type of store requested by the user and an evaluation of whether an existing file and file header having the user identification and file identification are stored at the file server.

11.   A method according to Claim 1, further comprising the steps of:

         generating an integrity key;



generating a message authentication code based on  
5 digital data of the file utilizing the integrity key;  
wherein the step of encrypting the file encryption  
key with the personal key to provide an encrypted file  
encryption key comprises the step of encrypting the  
10 file encryption key and the integrity key with the  
personal key to provide encrypted file encryption keys;  
and  
wherein the step of creating a file header  
containing the encrypted file encryption key comprises  
the step of creating a file header containing the  
15 encrypted file encryption keys and the message  
authentication code.

12. A method according to Claim 11, further  
comprising the step of storing the encrypted file and  
the file header associated with the encrypted file at a  
file server.

13. A method according to Claim 12, wherein the  
step of storing the encrypted file and the file header  
is followed by the steps of:

obtaining a passphrase to be utilized in  
5 decrypting the file;  
retrieving the encrypted file and the associated  
file header from the file server;  
generating the personal key from the passphrase to  
be utilized in decrypting the file;  
10 decrypting the encrypted file encryption keys with  
the personal key to provide a recovered file encryption  
key and a recovered integrity key;  
decrypting the file with the recovered file  
encryption key;

- 15            hashing the recovered integrity key with the  
decrypted file to provide a recovered message  
authentication code;  
             obtaining the message authentication code from the  
file header; and
- 20            comparing the recovered message authentication  
code with the message authentication code from the file  
header to confirm that the decrypted file corresponds  
to the file which generated the message authentication  
code from the file header.

14. A method according to Claim 11, further  
comprising the step of hashing the file encryption key  
with the integrity key to provide a verification value;  
and
- 5            wherein the step of encrypting the file encryption  
key and the integrity key with the personal key to  
provide encrypted file encryption keys comprises the  
step of encrypting the file encryption key, the  
integrity key and the verification value with the
- 10           personal key to provide the encrypted file encryption  
keys.

             15. A method according to Claim 14, further  
comprising the step of storing the encrypted file and  
the file header associated with the encrypted file at a  
file server.

16. A method according to Claim 15, wherein the  
step of storing the encrypted file and the file header  
is followed by the steps of:
- 5            obtaining a passphrase to be utilized in  
decrypting the file;  
             retrieving the encrypted file and the associated  
file header from the file server;

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generating the personal key from the passphrase to be utilized in decrypting the file;

10        decrypting the encrypted file encryption key with the personal key to provide a recovered file encryption key, a recovered integrity key and a recovered verification value;

15        hashing the recovered file encryption key and the recovered integrity key to provide a hash value;

      comparing the hash value and the recovered verification value; and

20        decrypting the file with the recovered file encryption key if the comparison of the hash value and the recovered verification value indicates that the values are equal.

17. A method according to Claim 16, further comprising the steps of:

5        hashing the recovered integrity key with the decrypted file to provide a recovered message authentication code;

      obtaining the message authentication code from the file header; and

10        comparing the recovered message authentication code with the message authentication code from the file header to confirm that the decrypted file corresponds to the file which generated the message authentication code from the file header.

15        18. A method according to Claim 1, further comprising the steps of:

      determining if a party other than an owner of the file is to have access to the file;

      obtaining a public key associated with the party other than the owner of the file if the party other



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encryption key comprises the step of encrypting the  
file encryption key and the integrity key with the  
10 personal key to provide encrypted file encryption keys;

wherein the step of creating a file header  
containing the encrypted file encryption key comprises  
the step of creating a file header containing the  
encrypted file encryption keys and the message  
15 authentication code;

wherein the step of encrypting the file encryption  
key with the public key of the party other than the  
owner of the file to provide a public key encrypted  
file encryption key if the party other than the owner  
20 of the file is to have access to the file comprises the  
step of encrypting the file encryption key and the  
integrity key with the public key to provide public key  
encrypted keys; and

wherein the step of incorporating the public key  
25 encrypted file encryption key in the file header  
associated with the file if the party other than the  
owner of the file is to have access to the file  
comprises the step of incorporating the public key  
encrypted keys in the file header.

22. A method according to Claim 21, further  
comprising the step of storing the encrypted file and  
the file header associated with the encrypted file at a  
file server.

23. A method according to Claim 22, wherein the  
step of storing the encrypted file and the file header  
is followed by the steps of:

5 retrieving the encrypted file and the associated  
file header from the file server;

obtaining a private key associated with public  
key;

10        decrypting the public key encrypted keys with the  
private key to provide a recovered file encryption key  
and a recovered integrity key;

      decrypting the file with the recovered file  
encryption key;

15        hashing the recovered integrity key with the  
decrypted file to provide a recovered message  
authentication code;

      obtaining a message authentication code from the  
file header; and

20        comparing the recovered message authentication  
code with the message authentication code from the file  
header to confirm that the decrypted file corresponds  
to the file which generated the message authentication  
code from the file header.

24. A method according to Claim 22, wherein the  
public key comprises a current public key and wherein  
the step of storing the encrypted file and the file  
header is followed by the steps of:

5        retrieving the file header associated with the  
encrypted file from the file server;

      generating the personal key from the passphrase  
associated with the file;

10        decrypting the encrypted file encryption key with  
the personal key to provide a recovered file encryption  
key;

      obtaining a new public key;

15        encrypting the file encryption key with the new  
public key to provide a new public key encrypted file  
encryption key;

      creating a new file header containing the new  
public key encrypted file encryption key; and

      storing the new file header associated with the  
file at the file server.

25. A method according to Claim 21, further comprising the step of hashing the file encryption key with the integrity key to provide a verification value; and

5        wherein the step of encrypting the file encryption key and the integrity key with the public key to provide public key encrypted keys comprises the step of encrypting the file encryption key, the integrity key and the verification value with the public key to  
10        provide the public key encrypted keys.

26. A method according to Claim 25, further comprising the step of storing the encrypted file and the file header associated with the encrypted file at a file server.

27. A method according to Claim 26, wherein the step of storing the encrypted file and the file header is followed by the steps of:

5        retrieving the encrypted file and the associated file header from the file server;

      obtaining a private key associated with the public key;

      decrypting the encrypted file encryption key with the private key to provide a recovered file encryption key, a recovered integrity key and a recovered  
10        verification value;

      hashing the recovered file encryption key and the recovered integrity key to provide a hash value;

      comparing the hash value and the recovered  
15        verification value; and

      decrypting the file with the recovered file encryption key if the comparison of the hash value and

the recovered verification value indicates that the values are equal.

28. A method according to Claim 27, further comprising the steps of:

hashing the recovered integrity key with the decrypted file to provide a recovered message authentication code;

obtaining a message authentication code from the file header; and

comparing the recovered message authentication code with the message authentication code from the file header to confirm that the decrypted file corresponds to the file which generated the message authentication code from the file header.

29. A system for controlling access to digital data in a file comprising:

means for obtaining a passphrase from a user;

means for generating a personal key based on the obtained passphrase;

means for generating a file encryption key;

means for encrypting the digital data in the file with the file encryption key to provide an encrypted file;

means for encrypting the file encryption key with the personal key to provide an encrypted file encryption key;

means for creating a file header containing the encrypted file encryption key; and

means for associating the file header with the encrypted file.



30. A system according to Claim 29, further comprising means for storing the encrypted file at a file server.

31. A system according to Claim 30, wherein the passphrase comprises a current passphrase, the system further comprising:

means for obtaining the file header associated  
5 with the encrypted file stored at the file server;  
means for generating the personal key from the  
current passphrase associated with the file;  
means for decrypting the encrypted file encryption  
key with the personal key to provide a recovered file  
10 encryption key;  
means for generating a new personal key based on a  
new passphrase;  
means for encrypting the file encryption key with  
the new personal key to provide a new encrypted file  
15 encryption key;  
means for creating a new file header containing  
the new encrypted file encryption key; and  
means for associating the new file header with the  
encrypted file stored at the file server.

32. A system according to Claim 31, further comprising means for storing the new file header associated with the encrypted file at the file server.

33. A system according to Claim 32, wherein a plurality of files have corresponding associated file headers containing encrypted file encryption keys encrypted with a corresponding plurality of personal  
5 keys based on the passphrase, and wherein the means for obtaining the file header associated with the encrypted file comprises means for retrieving the plurality of

file headers associated with the encrypted files from the file server;

10        wherein the means for generating the personal key from the current passphrase associated with the file comprises means for generating the plurality of personal keys from the current passphrase associated with the plurality of files;

15        wherein the means for decrypting the encrypted file encryption key with the personal key to provide a recovered file encryption key comprises means for decrypting the plurality of encrypted file encryption keys with corresponding ones of the plurality of personal keys to provide a corresponding plurality of file encryption keys;

20        wherein the means for generating a new personal key based on the new passphrase comprises means for generating a plurality of new personal keys based on the new passphrase;

25        wherein the means for encrypting the file encryption key with the new personal key to provide a new encrypted file encryption key comprises means for encrypting the plurality of file encryption keys with corresponding ones of the plurality of new personal keys to provide a plurality of new encrypted file encryption keys;

30        wherein the means for creating a new file header containing the new encrypted file encryption key comprises means for creating a plurality of new file headers containing the new encrypted file encryption keys; and

35        wherein the means for storing the new file header associated with the file at the file server comprises means for storing the plurality of new file headers associated with the plurality of files at the file server.

34. A system according to Claim 33, wherein the plurality of files comprise all files stored at the file server associated with a user and having a file header with an encrypted file encryption key encrypted with a personal key derived from the current passphrase.

35. A system according to Claim 30, further comprising:

means for obtaining a passphrase to be utilized in decrypting the file;

means for retrieving the encrypted file and the associated file header;

means for generating the personal key from the passphrase to be utilized in decrypting the file;

means for decrypting the encrypted file encryption key with the personal key to provide a recovered file encryption key; and

means for decrypting the file with the recovered file encryption key.

36. A system according to Claim 29, further comprising:

means for obtaining a user identification associated with an owner of the file;

means for obtaining a file identification associated with the file; and

wherein the means for generating a personal key based on the obtained passphrase comprises means for hashing the user identification, the passphrase and the file identification to provide the personal key.

37. A system according to Claim 36, further comprising means for storing the file and the associated file header at a file server.

38. A system according to Claim 37, wherein the means for storing the file and the associated file header at a file server comprises means for selectively storing the file and the file header based on a type of store requested by the user and an evaluation of whether an existing file and file header having the user identification and file identification are stored at the file server.

39. A system according to Claim 29, further comprising:

means for generating an integrity key;

means for generating a message authentication code based on digital data of the file utilizing the integrity key;

wherein the means for encrypting the file encryption key with the personal key to provide an encrypted file encryption key comprises means for encrypting the file encryption key and the integrity key with the personal key to provide encrypted file encryption keys; and

wherein the means for creating a file header containing the encrypted file encryption key comprises means for creating a file header containing the encrypted file encryption keys and the message authentication code.

40. A system according to Claim 39, further comprising means for storing the encrypted file and the file header associated with the encrypted file at a file server.

41. A system according to Claim 40, further comprising:

means for obtaining a passphrase to be utilized in decrypting the file;

5 means for retrieving the encrypted file and the associated file header from the file server;

means for generating the personal key from the passphrase to be utilized in decrypting the file;

10 means for decrypting the encrypted file encryption keys with the personal key to provide a recovered file encryption key and a recovered integrity key;

means for decrypting the file with the recovered file encryption key;

15 means for hashing the recovered integrity key with the decrypted file to provide a recovered message authentication code;

means for obtaining the message authentication code from the file header; and

20 means for comparing the recovered message authentication code with the message authentication code from the file header to confirm that the decrypted file corresponds to the file which generated the message authentication code from the file header.

42. A system according to Claim 39, further comprising means for hashing the file encryption key with the integrity key to provide a verification value; and

5 wherein the means for encrypting the file encryption key and the integrity key with the personal key to provide encrypted file encryption keys comprises means for encrypting the file encryption key, the integrity key and the verification value with the

10 personal key to provide the encrypted file encryption keys.

43. A system according to Claim 42, further comprising means for storing the encrypted file and the file header associated with the encrypted file at a file server.

44. A system according to Claim 43, further comprising:

means for obtaining a passphrase to be utilized in decrypting the file;

5 means for retrieving the encrypted file and the associated file header from the file server;

means for generating the personal key from the passphrase to be utilized in decrypting the file;

10 means for decrypting the encrypted file encryption key with the personal key to provide a recovered file encryption key, a recovered integrity key and a recovered verification value;

15 means for hashing the recovered file encryption key and the recovered integrity key to provide a hash value;

means for comparing the hash value and the recovered verification value; and

20 means for decrypting the file with the recovered file encryption key if the comparison of the hash value and the recovered verification value indicates that the values are equal.

45. A system according to Claim 44, further comprising:

5 means for hashing the recovered integrity key with the decrypted file to provide a recovered message authentication code;

means for obtaining the message authentication code from the file header; and

means for comparing the recovered message authentication code with the message authentication code from the file header to confirm that the decrypted file corresponds to the file which generated the message authentication code from the file header.

46. A system according to Claim 29, further comprising:

means for determining if a party other than an owner of the file is to have access to the file;

means for obtaining a public key associated with the party other than the owner of the file if the party other than the owner of the file is to have access to the file;

means for encrypting the file encryption key with the public key of the party other than the owner of the file to provide a public key encrypted file encryption key if the party other than the owner of the file is to have access to the file; and

means for incorporating the public key encrypted file encryption key in the header associated with the file if the party other than the owner of the file is to have access to the file.

47. A system according to Claim 46, further comprising means for storing the file header and the file at a file server.

48. A system according to Claim 47, further comprising:

means for retrieving the file and the file header from the file server;

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5 means for obtaining a private key associated with the public key;

means for decrypting the public key encrypted file encryption key with the private key to provide the file encryption key; and

10 means for decrypting the file with the file encryption key.

49. A system according to Claim 46, further comprising:

means for generating an integrity key;

5 means for generating a message authentication code based on digital data of the file utilizing the integrity key;

10 wherein the means for encrypting the file encryption key with the personal key to provide an encrypted file encryption key comprises the step of encrypting the file encryption key and the integrity key with the personal key to provide encrypted file encryption keys;

15 wherein the means for creating a file header containing the encrypted file encryption key comprises means for creating a file header containing the encrypted file encryption keys and the message authentication code;

20 wherein the means for encrypting the file encryption key with the public key of the party other than the owner of the file to provide a public key encrypted file encryption key if the party other than the owner of the file is to have access to the file comprises means for encrypting the file encryption key and the integrity key with the public key to provide public key encrypted keys; and

25 wherein the means for incorporating the public key encrypted file encryption key in the file header



associated with the file if the party other than the owner of the file is to have access to the file comprises means for incorporating the public key encrypted keys in the file header.

50. A system according to Claim 49, further comprising means for storing the encrypted file and the file header associated with the encrypted file at a file server.

51. A system according to Claim 50, further comprising:

means for retrieving the encrypted file and the associated file header from the file server;  
means for obtaining a private key associated with public key;  
means for decrypting the public key encrypted keys with the private key to provide a recovered file encryption key and a recovered integrity key;  
means for decrypting the file with the recovered file encryption key;  
means for hashing the recovered integrity key with the decrypted file to provide a recovered message authentication code;  
means for obtaining a message authentication code from the file header; and  
means for comparing the recovered message authentication code with the message authentication code from the file header to confirm that the decrypted file corresponds to the file which generated the message authentication code from the file header.

52. A system according to Claim 50, wherein the public key comprises a current public key, the system further comprising:



means for retrieving the encrypted file and the  
associated file header from the file server;

5 means for obtaining a private key associated with  
the public key;

means for decrypting the encrypted file encryption  
key with the private key to provide a recovered file  
encryption key, a recovered integrity key and a  
10 recovered verification value;

means for hashing the recovered file encryption  
key and the recovered integrity key to provide a hash  
value;

means for comparing the hash value and the  
15 recovered verification value; and

means for decrypting the file with the recovered  
file encryption key if the comparison of the hash value  
and the recovered verification value indicates that the  
values are equal.

56. A system according to Claim 55, further  
comprising:

means for hashing the recovered integrity key with  
the decrypted file to provide a recovered message  
5 authentication code;

means for obtaining a message authentication code  
from the file header; and

means for comparing the recovered message  
authentication code with the message authentication  
10 code from the file header to confirm that the decrypted  
file corresponds to the file which generated the  
message authentication code from the file header.

57. A computer program product for controlling  
15 access to digital data in a file comprising:

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a computer readable storage medium having computer readable program code embodied therein, the computer readable program code comprising:

computer readable program code which obtains a  
20 passphrase from a user;

computer readable program code which generates a personal key based on the obtained passphrase;

computer readable program code which generates a file encryption key;

25 computer readable program code which encrypts the digital data in the file with the file encryption key to provide an encrypted file;

computer readable program code which encrypts the file encryption key with the personal key to provide an  
30 encrypted file encryption key;

computer readable program code which creates a file header containing the encrypted file encryption key; and

35 computer readable program code which associates the file header with the encrypted file.

58. A computer program product according to Claim 57, further comprising computer readable program code which stores the encrypted file at a file server.

59. A computer program product according to Claim 58, wherein the passphrase comprises a current passphrase, the computer program product further comprising:

5 computer readable program code which obtains the file header associated with the encrypted file stored at the file server;

computer readable program code which generates the personal key from the current passphrase associated  
10 with the file;

computer readable program code which decrypts the encrypted file encryption key with the personal key to provide a recovered file encryption key;

15 computer readable program code which generates a new personal key based on a new passphrase;

computer readable program code which encrypts the file encryption key with the new personal key to provide a new encrypted file encryption key;

20 computer readable program code which creates a new file header containing the new encrypted file encryption key; and

computer readable program code which associates the new file header with the encrypted file stored at the file server.

60. A computer program product according to Claim 59, further comprising computer readable program code which stores the new file header associated with the encrypted file at the file server.

61. A computer program product according to Claim 60, wherein a plurality of files have corresponding associated file headers containing encrypted file encryption keys encrypted with a corresponding  
5 plurality of personal keys based on the passphrase, and wherein the computer readable program code which obtains the file header associated with the encrypted file comprises computer readable program code which retrieves the plurality of file headers associated with  
10 the encrypted files from the file server;

wherein the computer readable program code which generates the personal key from the current passphrase associated with the file comprises computer readable program code which generates the plurality of personal

15 keys from the current passphrase associated with the plurality of files;

wherein the computer readable program code which decrypts the encrypted file encryption key with the personal key to provide a recovered file encryption key

20 comprises computer readable program code which decrypts the plurality of encrypted file encryption keys with corresponding ones of the plurality of personal keys to provide a corresponding plurality of file encryption keys;

25 wherein the computer readable program code which generates a new personal key based on the new passphrase comprises computer readable program code which generates a plurality of new personal keys based on the new passphrase;

30 wherein the computer readable program code which encrypts the file encryption key with the new personal key to provide a new encrypted file encryption key comprises computer readable program code which encrypts the plurality of file encryption keys with

35 corresponding ones of the plurality of new personal keys to provide a plurality of new encrypted file encryption keys;

wherein the computer readable program code which creates a new file header containing the new encrypted file encryption key comprises computer readable program code which creates a plurality of new file headers containing the new encrypted file encryption keys; and

40 wherein the computer readable program code which stores the new file header associated with the file at the file server comprises computer readable program code which stores the plurality of new file headers associated with the plurality of files at the file server.

45

62. A computer program product according to Claim 5  
61, wherein the plurality of files comprise all files stored at the file server associated with a user and having a file header with an encrypted file encryption key encrypted with a personal key derived from the current passphrase.

63. A computer program product according to Claim 58, further comprising:

computer readable program code which obtains a passphrase to be utilized in decrypting the file;

5 computer readable program code which retrieves the encrypted file and the associated file header;

computer readable program code which generates the personal key from the passphrase to be utilized in decrypting the file;

10 computer readable program code which decrypts the encrypted file encryption key with the personal key to provide a recovered file encryption key; and

computer readable program code which decrypts the file with the recovered file encryption key.

64. A computer program product according to Claim 57, further comprising:

5 computer readable program code which obtains a user identification associated with an owner of the file;

computer readable program code which obtains a file identification associated with the file; and

10 wherein the computer readable program code which generates a personal key based on the obtained passphrase comprises computer readable program code which hashes the user identification, the passphrase and the file identification to provide the personal key.

65. A computer program product according to Claim 64, further comprising computer readable program code which stores the file and the associated file header at a file server.

66. A computer program product according to Claim 65, wherein the computer readable program code which stores the file and the associated file header at a file server comprises computer readable program code which selectively stores the file and the file header based on a type of store requested by the user and an evaluation of whether an existing file and file header having the user identification and file identification are stored at the file server.

67. A computer program product according to Claim 57, further comprising:

computer readable program code which generates an integrity key;

computer readable program code which generates a message authentication code based on digital data of the file utilizing the integrity key;

wherein the computer readable program code which encrypts the file encryption key with the personal key to provide an encrypted file encryption key comprises computer readable program code which encrypts the file encryption key and the integrity key with the personal key to provide encrypted file encryption keys; and

wherein the computer readable program code which creates a file header containing the encrypted file encryption key comprises computer readable program code which creates a file header containing the encrypted file encryption keys and the message authentication code.





70. A computer program product according to Claim 67, further comprising computer readable program code which hashes the file encryption key with the integrity key to provide a verification value; and

5 wherein the computer readable program code which encrypts the file encryption key and the integrity key with the personal key to provide encrypted file encryption keys comprises computer readable program code which encrypts the file encryption key, the  
10 integrity key and the verification value with the personal key to provide the encrypted file encryption keys.

71. A computer program product according to Claim 70, further comprising computer readable program code which stores the encrypted file and the file header associated with the encrypted file at a file server.

72. A computer program product according to Claim 71, further comprising:

computer readable program code which obtains a passphrase to be utilized in decrypting the file;

5 computer readable program code which retrieves the encrypted file and the associated file header from the file server;

computer readable program code which generates the personal key from the passphrase to be utilized in  
10 decrypting the file;

computer readable program code which decrypts the encrypted file encryption key with the personal key to provide a recovered file encryption key, a recovered integrity key and a recovered verification value;

15 computer readable program code which hashes the recovered file encryption key and the recovered integrity key to provide a hash value;

computer readable program code which compares the  
hash value and the recovered verification value; and  
20 computer readable program code which decrypts the  
file with the recovered file encryption key if the  
comparison of the hash value and the recovered  
verification value indicates that the values are equal.

73. A computer program product according to Claim  
72, further comprising:

computer readable program code which hashes the  
recovered integrity key with the decrypted file to  
5 provide a recovered message authentication code;  
computer readable program code which obtains the  
message authentication code from the file header; and  
computer readable program code which compares the  
recovered message authentication code with the message  
10 authentication code from the file header to confirm  
that the decrypted file corresponds to the file which  
generated the message authentication code from the file  
header.

74. A computer program product according to Claim  
57, further comprising:

computer readable program code which  
determinesdetermining if a party other than an owner of  
5 the file is to have access to the file;  
computer readable program code which obtains a  
public key associated with the party other than the  
owner of the file if the party other than the owner of  
the file is to have access to the file;  
10 computer readable program code which encrypts the  
file encryption key with the public key of the party  
other than the owner of the file to provide a public  
key encrypted file encryption key if the party other

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than the owner of the file is to have access to the  
file; and

computer readable program code which incorporates  
incorporating the public key encrypted file encryption  
key in the header associated with the file if the party  
other than the owner of the file is to have access to  
the file.

75. A computer program product according to Claim  
74, further comprising computer readable program code  
which stores the file header and the file at a file  
server.

76. A computer program product according to Claim  
75, further comprising:

computer readable program code which retrieves the  
file and the file header from the file server;

computer readable program code which obtains a  
private key associated with the public key;

computer readable program code which decrypts the  
public key encrypted file encryption key with the  
private key to provide the file encryption key; and

computer readable program code which decrypts the  
file with the file encryption key.

77. A computer program product according to Claim  
74, further comprising:

computer readable program code which generates an  
integrity key;

computer readable program code which generates a  
message authentication code based on digital data of  
the file utilizing the integrity key;

wherein the computer readable program code which  
encrypts the file encryption key with the personal key  
to provide an encrypted file encryption key comprises

the step of encrypting the file encryption key and the integrity key with the personal key to provide encrypted file encryption keys;

15        wherein the computer readable program code which creates a file header containing the encrypted file encryption key comprises computer readable program code which creates a file header containing the encrypted file encryption keys and the message authentication code;

20        wherein the computer readable program code which encrypts the file encryption key with the public key of the party other than the owner of the file to provide a public key encrypted file encryption key if the party other than the owner of the file is to have access to  
25        the file comprises computer readable program code which encrypts the file encryption key and the integrity key with the public key to provide public key encrypted keys; and

30        wherein the computer readable program code which incorporates the public key encrypted file encryption key in the file header associated with the file if the party other than the owner of the file is to have access to the file comprises computer readable program code which incorporates the public key encrypted keys  
35        in the file header.

78. A computer program product according to Claim 77, further comprising computer readable program code which stores the encrypted file and the file header associated with the encrypted file at a file server.

79. A computer program product according to Claim 78, further comprising:

computer readable program code which retrieves the encrypted file and the associated file header from the file server;

computer readable program code which obtains a private key associated with public key;

computer readable program code which decrypts the public key encrypted keys with the private key to provide a recovered file encryption key and a recovered integrity key;

computer readable program code which decrypts the file with the recovered file encryption key;

computer readable program code which hashes the recovered integrity key with the decrypted file to provide a recovered message authentication code;

computer readable program code which obtains a message authentication code from the file header; and

computer readable program code which compares the recovered message authentication code with the message authentication code from the file header to confirm that the decrypted file corresponds to the file which generated the message authentication code from the file header.

80. A computer program product according to Claim 78, wherein the public key comprises a current public key, the computer program product further comprising:

computer readable program code which retrieves the file header associated with the encrypted file from the file server;

computer readable program code which generates the personal key from the passphrase associated with the file;

computer readable program code which decrypts the encrypted file encryption key with the personal key to provide a recovered file encryption key;

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computer readable program code which obtains a new public key;

15 computer readable program code which encrypts the file encryption key with the new public key to provide a new public key encrypted file encryption key;

computer readable program code which creates a new file header containing the new public key encrypted file encryption key; and

20 computer readable program code which stores the new file header associated with the file at the file server.

81. A computer program product according to Claim 77, further comprising computer readable program code which hashes the file encryption key with the integrity key to provide a verification value; and

5 wherein the computer readable program code which encrypts the file encryption key and the integrity key with the public key to provide public key encrypted keys comprises computer readable program code which encrypts the file encryption key, the integrity key and the verification value with the public key to provide the public key encrypted keys.

82. A computer program product according to Claim 81, further comprising computer readable program code which stores the encrypted file and the file header associated with the encrypted file at a file server.

83. A computer program product according to Claim 82, further comprising:

5 computer readable program code which retrieves the encrypted file and the associated file header from the file server;





## SECURE DATA STORAGE AND RETRIEVAL IN A CLIENT-SERVER ENVIRONMENT

### Abstract of the Disclosure

Methods, systems and computer program products are provided for controlling access to digital data in a file by obtaining a passphrase from a user and generating a personal key based on the obtained  
5        passphrase. A file encryption key is generated and the digital data in the file encrypted with the file encryption key to provide an encrypted file. The file encryption key is encrypted with the personal key to provide an encrypted file encryption key. A file  
10        header containing the encrypted file encryption key and associated with the encrypted file. The encrypted file and the file header associated with the encrypted file may be stored at a file server.

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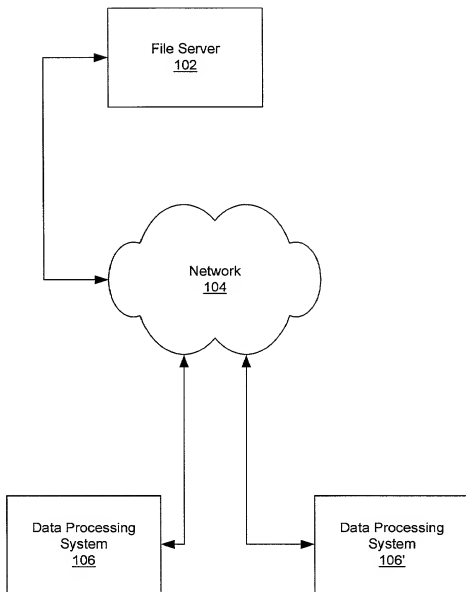


Figure 1

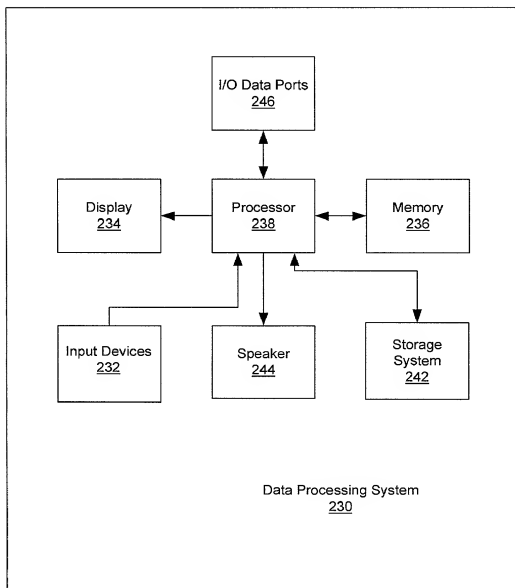


Figure 2

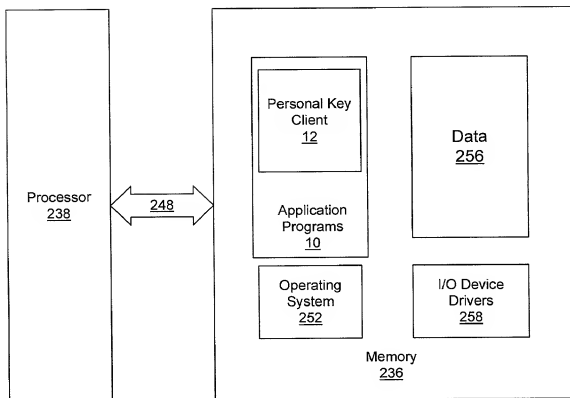
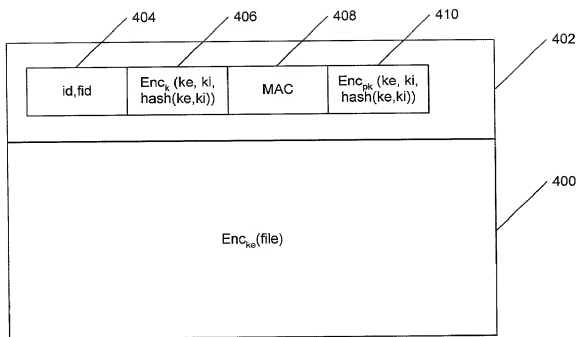
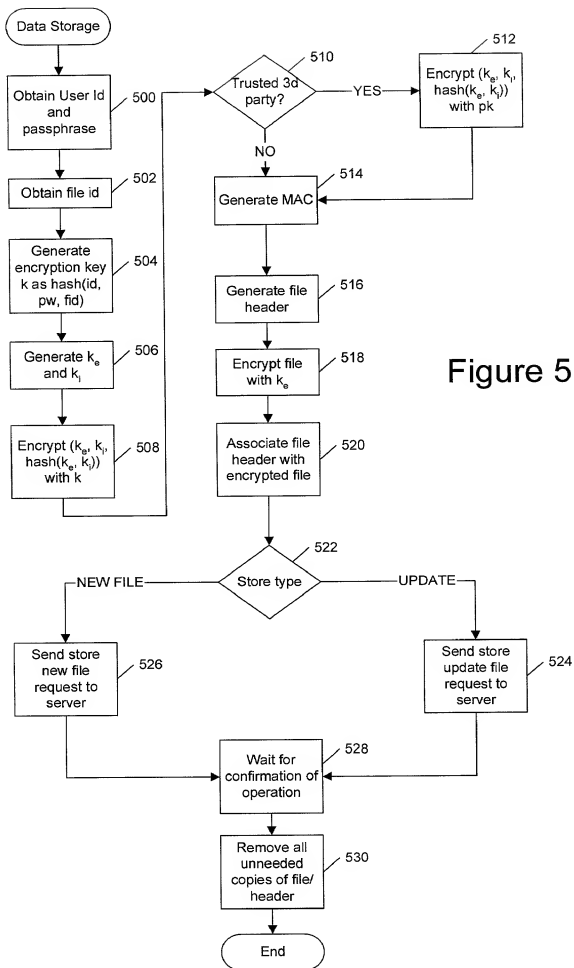


Figure 3

09842979 in 00000000



### Figure 4



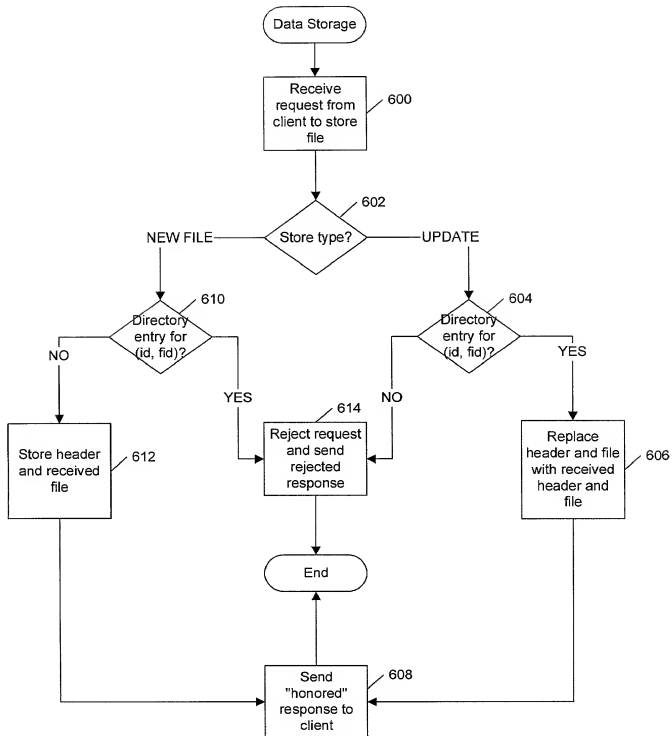


Figure 6

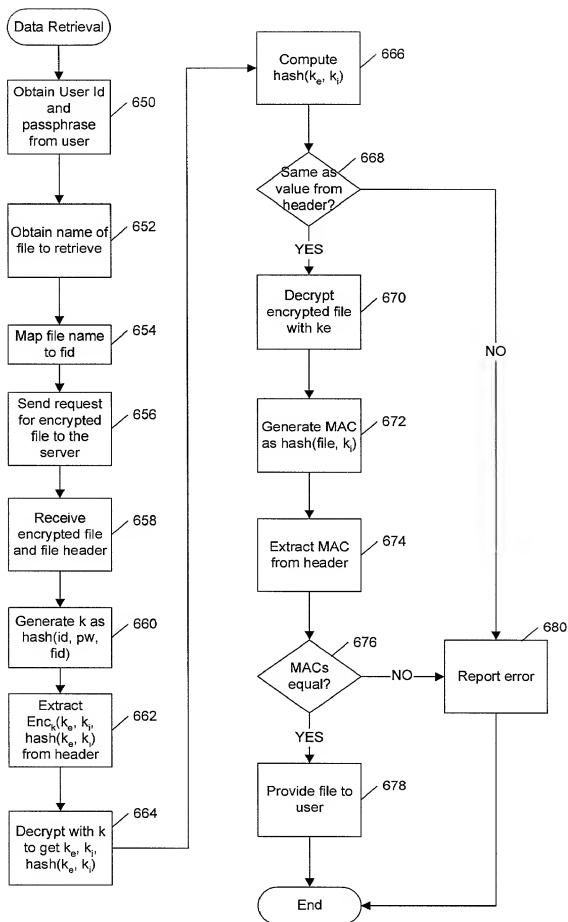


Figure 7



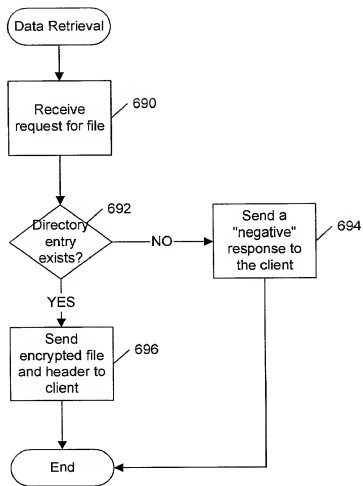


Figure 8

```

graph TD
    Start([Data Retrieval/Trusted Party]) --> 700[Obtain name of file to retrieve]
    700 --> 702[Map file name to fid and create tuple (id, fid)]
    702 --> 704[Send request for encrypted file to the server as request for access by trusted third party]
    704 --> 706[Receive encrypted file and file header]
    706 --> 708[Extract Enc_{pk(k_e, k_i)}, hash(k_e, k_i) from header]
    708 --> 710[Decrypt with sk to get k_e, k_i, hash(k_e, k_i)]
    710 --> 712[Compute hash(k_e, k_i)]
    712 --> 714{Same as value from header?}
    714 -- YES --> 716[Decrypt encrypted file with k_e]
    716 --> 718[Generate MAC as hash(file, k_i)]
    718 --> 720[Extract MAC from header]
    720 --> 722{MACs equal?}
    722 -- YES --> 724[Provide file to trusted third party]
    724 --> End1([End])
    722 -- NO --> 726[Report error]
    714 -- NO --> 726
    726 --> End1
  
```

### Figure 9

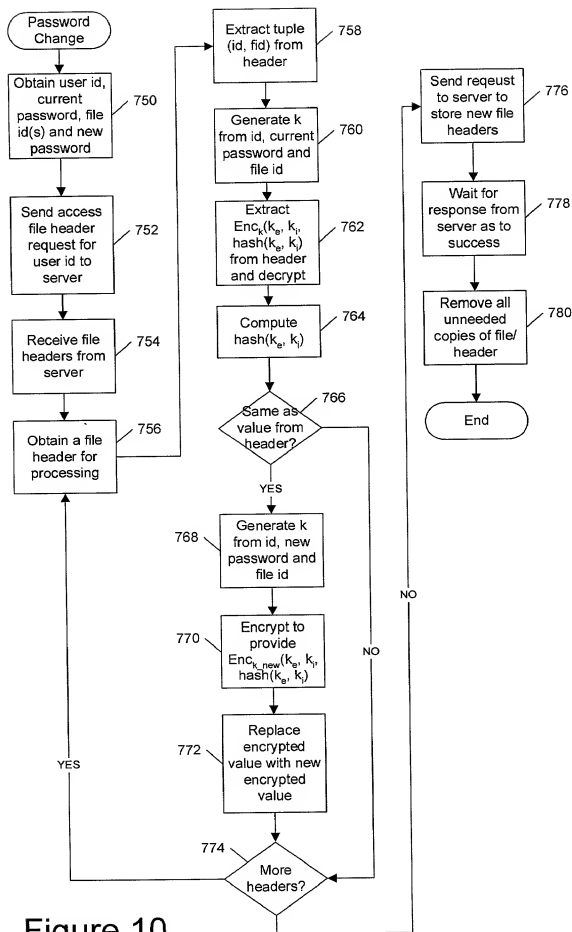


Figure 10

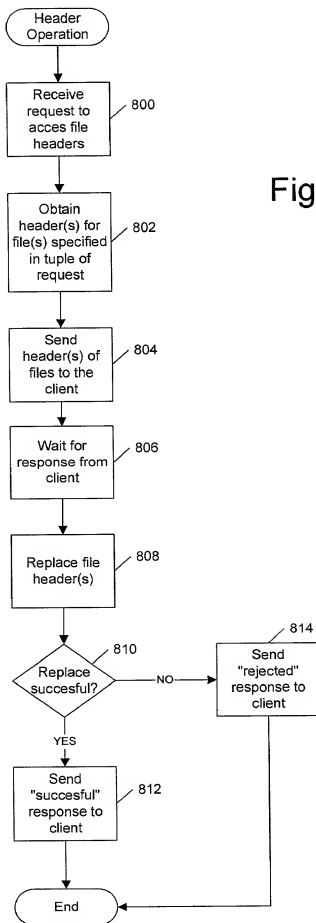


Figure 11

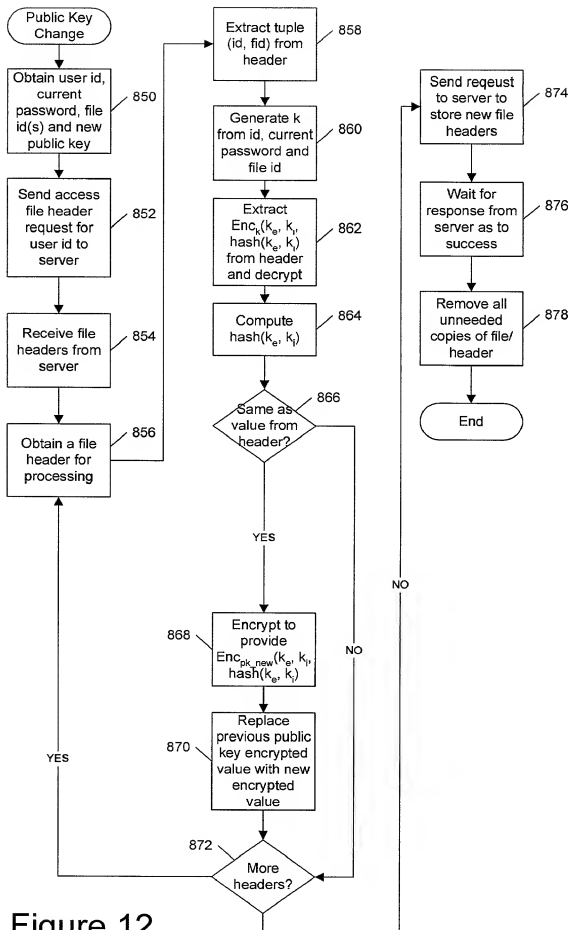


Figure 12

**DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION**

Attorney Docket No. 5577-203

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **SECURE DATA STORAGE AND RETRIEVAL IN A CLIENT-SERVER ENVIRONMENT**,

the specification of which

☒ is attached hereto

OR

☐ was filed on \_\_\_\_\_ as United States Application No. \_\_\_\_\_ or PCT International Application Number \_\_\_\_\_ and was amended on \_\_\_\_\_ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37 Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States of America, listed below and have also identified below any foreign application for patent or inventor's certificate, or of any PCT International application having a filing date before that of the application on which priority is claimed.

None			<input type="checkbox"/> Yes <input type="checkbox"/> No
Number	Country	MM/DD/YYYY Filed	Priority Claimed

			<input type="checkbox"/> Yes <input type="checkbox"/> No
Number	Country	MM/DD/YYYY Filed	Priority Claimed

			<input type="checkbox"/> Yes <input type="checkbox"/> No
Number	Country	MM/DD/YYYY Filed	Priority Claimed



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